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G2J JGF
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(54) Optical waveguide device having surface relief diffraction grating

(57) An optical waveguide device incorporating a surface-relief diffraction grating structure 6 operating in a first-order spatial harmonic mode. The grating structure 6 comprises the superposition of two or more gratings each having a respective period, and at least two of which 2, 4 are dissimilar grating periods. The composite gratings in the grating structure may be chosen so as to enable the device to have a predetermined output spectrum. As shown, the grating 6 is applied to a distributed feedback laser diode 10 having a cavity 12 within which there is an active layer 14. The grating 6 is etched into a guide layer 16. The optical waveguide device may be an optical fibre grating filter 20.
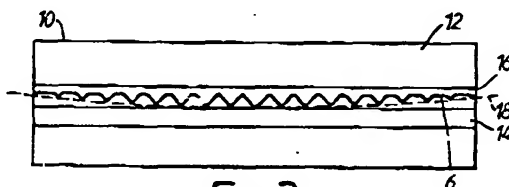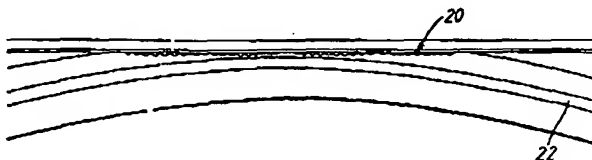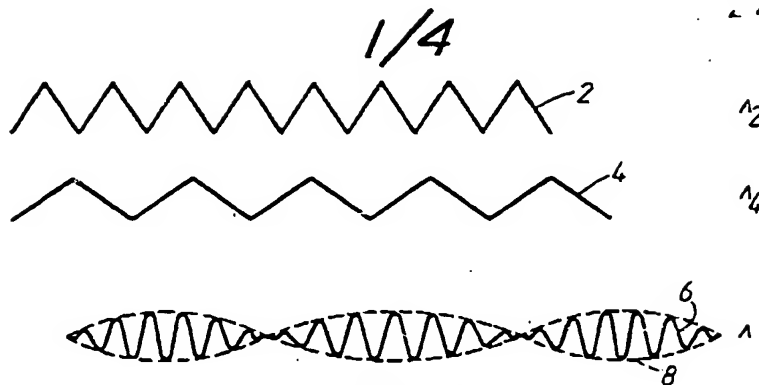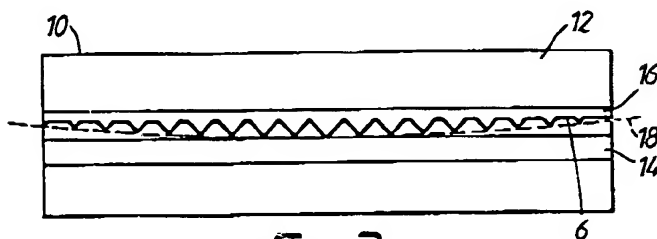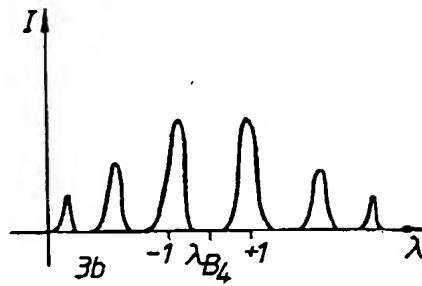

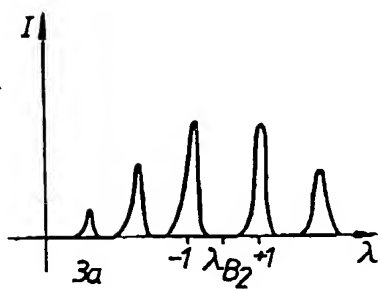FIG. 2.
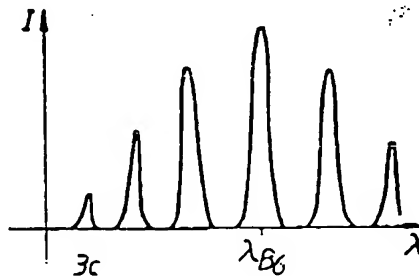

FIG. 6.

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FIG. 1.
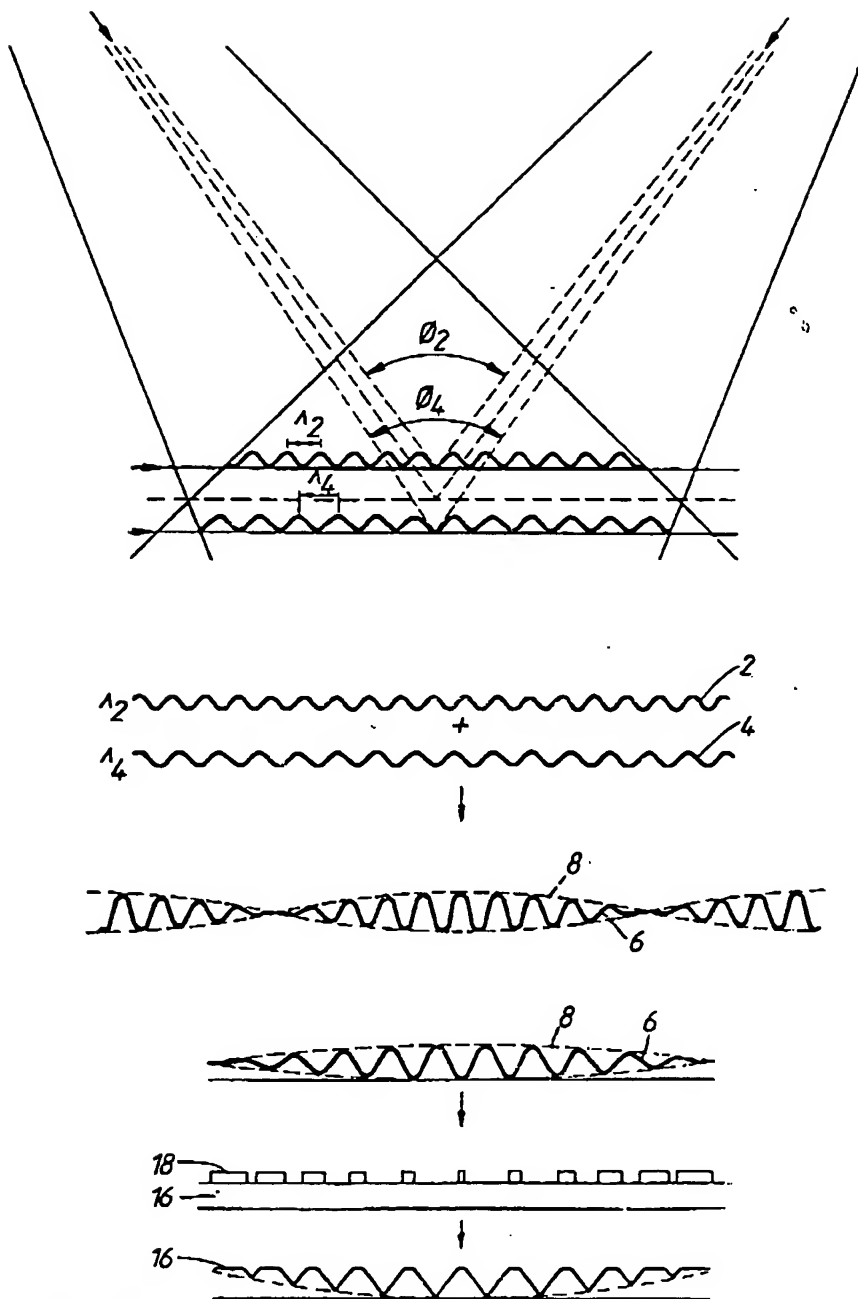

FIG. 2.

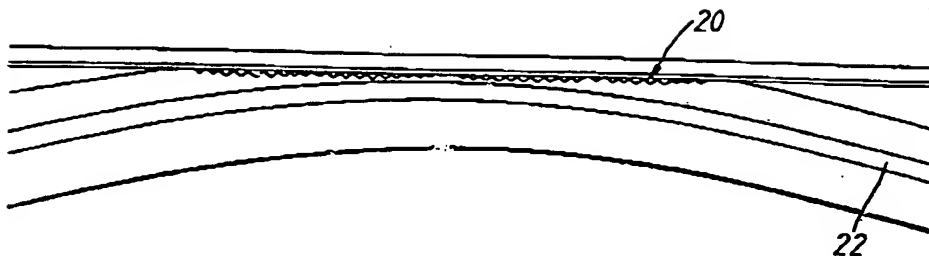FIG. 3.

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FIG.4.

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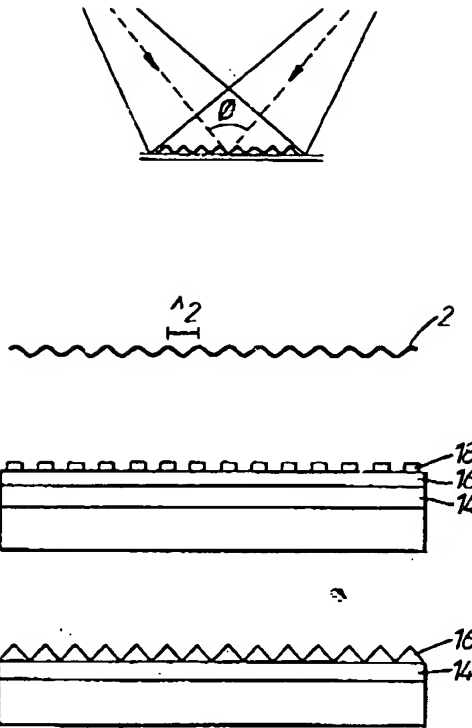
FIG.5.

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FIG. 6.

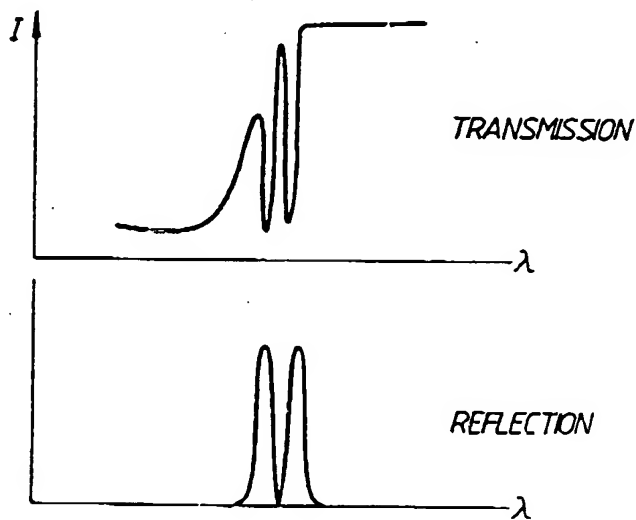FIG. 7.

OPTICAL WAVEGUIDE DEVICE

This invention relates to an optical waveguide device. It relates particularly to such a device which includes a single surface-relief diffraction grating, operating in a first-order spatial harmonic mode.

One example of an optical waveguide device is a Distributed Feedback (DFB) laser diode the spectral properties of which are dependent principally on the presence of a surface-relief diffraction grating in the structure. The grating can be formed as a second-order corrugation which acts as a periodically varying optical waveguide boundary, and allows coupling between the forward and backward propagating waves.

The period of a second-order grating is equal to twice the Bragg wavelength. There are two main reasons for choosing second-order gratings. These are (a) first-order gratings would be more difficult to produce because the grating period would be very small, that is less than 0.25 micrometres, and (b) second-order gratings have a saw-tooth profile with an inherent high amplitude harmonic component acting as the first-order grating. The structure of the present invention, therefore, operates in a first-order spatial harmonic mode whether directly in the first-order or indirectly at the first-order spatial harmonic component of a multiple order grating.

In a DFB laser construction formed without end reflectors, the longitudinal modes are symmetrically distributed about the Bragg wavelength. Consequently, this type of DFB laser has two dominant competing modes, neither of which is preferred and the device tends

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to switch from ne dominant mode to the other at random. Thus, the
device suffers from not having a stable output at a single wavelength
for the lasing operation.

A more common type of DFB laser construction includes end
reflectors, such that the longitudinal mode spectrum is
assymmetrically distributed about the Bragg wavelength. This type
of DFB laser has one dominant mode and therefore has a stable
output at a certain wavelength.

Reflection occurs as a result of cleaved facets. The position of
the facet relative to the grating will effect the phase relationship
between forward and backward waves at the facet.

A previously proposed DFB laser diode device capable of
having an output characterised by one dominant longitudinal mode
incorporates a single cleaved facet in the surface-relief diffraction
grating. This causes a sharp phase-shift in the diffraction grating
corrugations at the position of the cleaved facet. This mode
assymmetry, which is thereby introduced, is conditional upon the
exact position of the cleaved facet within a grating period. Since the
dimensions involved are extremely small, typically the grating
period is less than O.5 micrometres, it is impractical to control and
measure the position of the cleaved facet. Hence in any one
production batch of DFB laser diode devices only a fraction of this
batch would exhibit well defined single mode characteristics.

.It is an object of the present invention to provide an optical
waveguide device incorporating a diffraction grating whereby the
output mode characteristics can be predetermined regardless of the
position of discontinuities in the grating within the grating period.

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According to the present invention there is pr vided an optical waveguide device including a surface - relief diffraction grating structure operating in a first-order spatial harmonic mode, whereby the grating structure comprises the superposition of two or more gratings each having a respective period, and at least two of the gratings having dissimilar periods.

Preferably the device provides an output spectrum having one dominant longitudinal mode. The optical waveguide device may be a distributed feedback laser diode and in another embodiment the optical waveguide device may be an optical fibre grating filter.

By way of example, some particular embodiments of the present invention will now further be described with reference to the accompanying drawings, of which:

Figure 1   is a schematic diagram of a superposition of two gratings to provide a grating structure in accordance with a preferred embodiment of the present invention;

Figure 2   is a schematic diagram of a DFB laser incorporating the preferred embodiment of the present invention;

Figure 3 a,b, and c   are exemplary diagrams of the intensity spectra obtained from the DFB laser diode as illustrated in Figure 2;

Figure 4   is a plan diagram of the formation stages of a grating according to the prior art.

Figure 5   is a plan diagram of the formation stages of the grating structure according to the preferred embodiment of the present inventing;

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Figure 6   is a schematic diagram of an optical fibre grating filter in accordance with another embodiment of the present invention; and

Figure 7   is an exemplary diagram of the intensity spectrum obtained from the optical fibre grating filter shown in Figure 6.

Referring to Figure 1, there is shown two gratings 2, 4 each having a different period $\sim_2, \sim_4$. The incoherent superposition of the gratings 2, 4 result in a grating structure 6. This grating 6 has a substantially regular but varying period, which incorporates a moire envelope 8.

The gratings 2, 4 are second-order gratings, having the periods $\sim_2, \sim_4$ and which both obey the following relationship

$$\lambda_B = 2n_{eff} \sim$$

where λ_B is the Bragg wavelength and n_{eff} is the effective waveguide refractive index. Although, the gratings 2, 4 are second-order, they have an inherent high amplitude harmonic component thus appearing as first-order gratings.

Figure 2 illustrates the grating 6 when applied to a distributed feedback (DFB) laser diode 10. The DFB laser diode 10 comprises a cavity 12 within which resides an active layer 14. Parallel to the said active layer 14 is the grating 6 etched into a guide layer 16.

The grating 6 provides a periodic waveguide boundary for enabling forward and backward propagating waves in the active layer 14 to be coupled. The effect of the grating 6 is to provide two gratings 2, 4 of differing periods $\sim_2, \sim_4$, within the same cavity 12. Consequently, it appears as if there are two DFB lasers each producing a characteristic intensity spectrum. The resultant

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intensity spectrum from the DFB laser 10 using the grating 6 is a superposition of these two intensity spectra.

Certain pairs of gratings 2, 4 can be chosen such that there exists one common longitudinal mode in the output spectrum. As shown in Figure 3, the -1 dominant mode from the grating 2 has the same wavelength as the +1 dominant mode from the grating 4. The superposition of these modes enables the DFB laser 10 incorporating the grating 6 to have one common mode as shown in Figure 3c.

Obviously the single gratings 2, 4 could be chosen such that the +1 dominant mode from the grating 2 corresponds to the -1 dominant mode from the grating 4.

Furthermore, the presence of the grating 6 in the DFB laser 10 nables one mode of the intensity spectrum to predominate regardless of the position of the discontinuities in the grating 6 within the grating period.

A known method for producing the grating 2 or 4 consists of a preferential etch technique as shown in Figure 4. A layer of photoresist 18 of an approximate depth of 80 nanometres is d posited on the guide layer 16. This layer of photoresist 18 is then exposed to a two-beam interference pattern. After development a regular pattern of parallel resist stripes 18 is formed which then acts as a mask for a preferential chemical etch. The preferential etch engraves the guide layer 16, thus producing a series of parallel, well-defined, V-shaped grooves to form the grating 2.

The period of this grating 2. $\wedge_2$ is given by:

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where λ = wavelength of the interference beams, and $\emptyset$ = angle between the interference beams.

In order to produce the grating 6, two gratings need to be formed in the guide layer 16. Consequently the photoresist layer must be exposed to two intereference patterns. This can be achiev d by varying the angle between the interfering beams.

If the interfering beams are diverging and of equal curvature at the plane of the photoresist layer 18, then this merely requires a translation of the grating 6. Such a translation being in a direction perpendicular to the plane of the photoresist layer 18 as shown in Figure 5. Alternatively, if the interference beams are collimated then the grating 6 can be tilted through a few degrees in order to vary $\emptyset$. Hence the periods of the two single gratings 2, 4 are

$$\wedge_2 = \frac{\lambda}{2 \sin \emptyset_2 / 2}$$

$$\wedge_4 = \frac{\lambda}{2 \sin \emptyset_4 / 2}$$

The grating 6 is then subjected to the preferential chemical etch, thus forming the grating 6 with a substantially regular but varying period.

Another method for forming the photoresist pattern is employing an electron beam technique.

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Another embodiment of the present invention is shown in Figure 6, which illustrates an optical fibre grating filter 20. The optical fibre grating filter 20 is a first-order grating etched into a fibre core 22. The presence of the optical fibre grating filter 20 permits coupling of forward and backward propagating waves travelling within the fibre core 22.

The transmission and reflection spectra from using such an optical fibre grating filter 20 are given in Figure 7. The reflection spectrum is characterised by two peaks whereas the reflection spectrum for a known grating only has one peak. Similarly the transmission spectrum is characterised by two peaks when using the optical fibre grating filter 20.

Consequently the application of optical fibre grating filters enables the reflection and transmission characteristics of the intensity spectra to be predetermined.

The present invention has been described with reference to the foregoing embodiments. However, modification may be introduced without departing from the scope of the present invention.

For example, grating structures comprising three or more gratings may be used in DFB lasers to ensure that one mode predominates. Alternatively, it may be desirable to obtain an intensity spectrum from a DFB laser, such that more than one stable mode predominates through the application of multiple gratings.

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CLAIMS:

1.   An optical waveguide device including a surface-relief diffraction grating structure capable of operating in a first-order spatial harmonic mode, in which the grating structure comprises a single grating which exhibits amplitude and periodic variations representative of two or more grating images having dissimilar grating periods.

2.   An optical waveguide device as claimed in Claim 1, wherein in operation the device provides an output spectrum having one dominant longitudinal mode.

3.   An optical waveguide device as claimed in Claim 1 or Claim 2, wherein the device is a distributed feedback laser diode.

4.   An optical waveguide device as claimed in Claim 1 or Claim 2, wherein the device is an optical fibre grating filter.

5.   An optical waveguide device substantially as hereinbefore described with reference to any one of Figures 1, 2, 3, 6 and 7.

6.   An optical waveguide device substantially as hereinbefore described.

7.   A method of constructing an optical waveguide as claimed in any one of Claims 1 to 6, in which a diffraction grating is formed from two or more grating images having dissimilar grating periods, comprising the step of superimposing said images one on the other such that the image patterns will be added together incoherently to form a single grating.

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8.   A method of constructing an optical waveguide device as claimed in any one of Claims 1 to 6, substantially as hereinbefore described.